Polymeric Electronic and Optical Dielectric Materials: Opportunities and Realities

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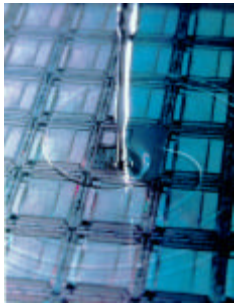
Electronic Materials at AlliedSignal

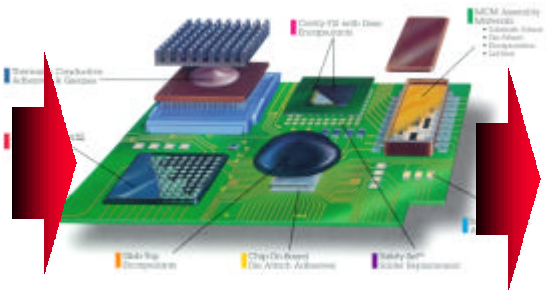
AlliedSignal Electronic Materials

Semiconductor Chip



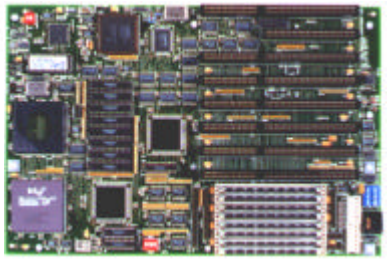
- **A**dvanced **M**icroelectronic **M**aterials

Package



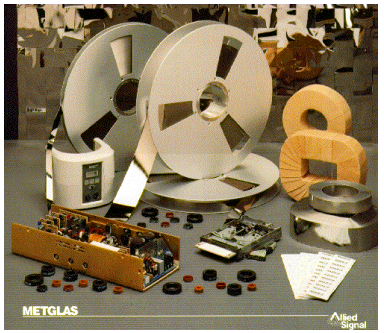
- **A**lliedSignal **S**ubstrate **T**echnology and **I**nterconnect.

Printed Wiring Board Substrate

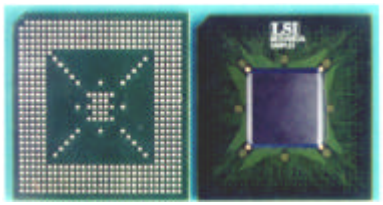


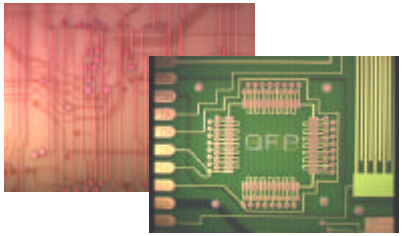
- **Laminate Systems**
- **Oak Mitsui**

Component



- **A**morphous **M**etals
- **Optical Devices**

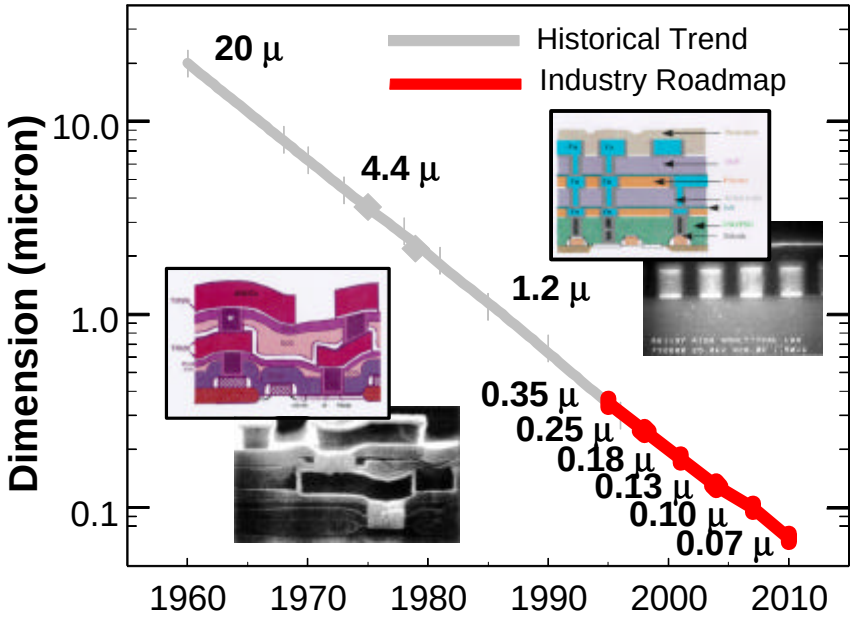


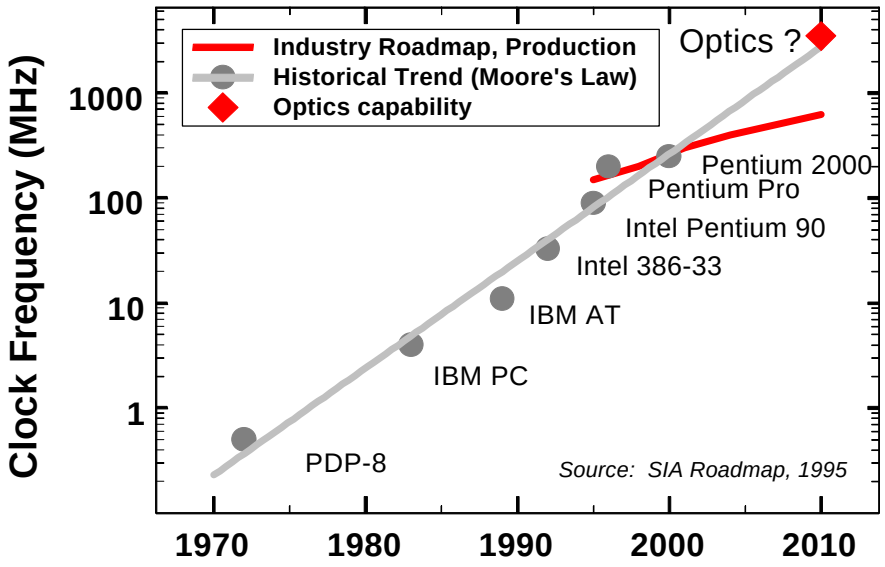


The Growth Center:

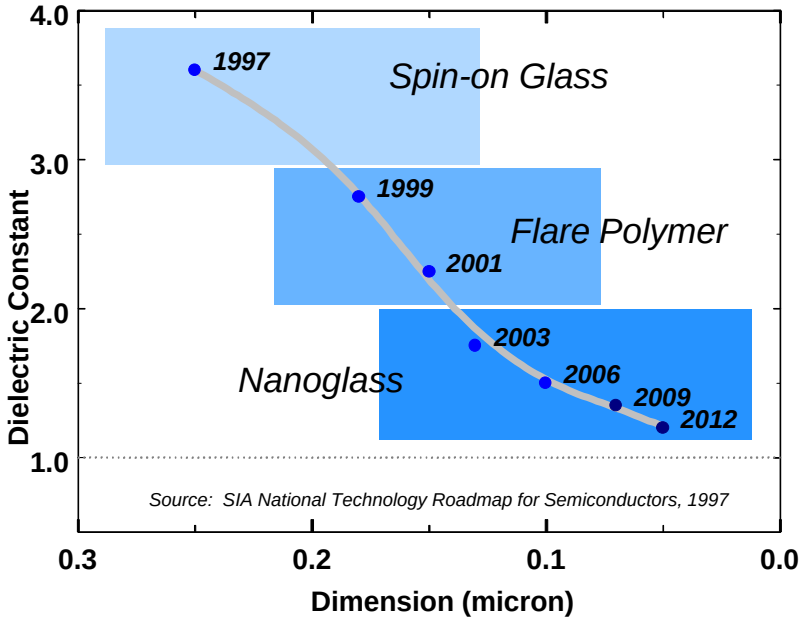
- Opportunity development through marketing and technology.
- Strategic interface with oem's, government, industry, professional societies, universities.

Electronics industry roadmaps drive business opportunity





IC Inter-level dielectric roadmap:



New technologies required to meet needs of increasingly smaller devices:

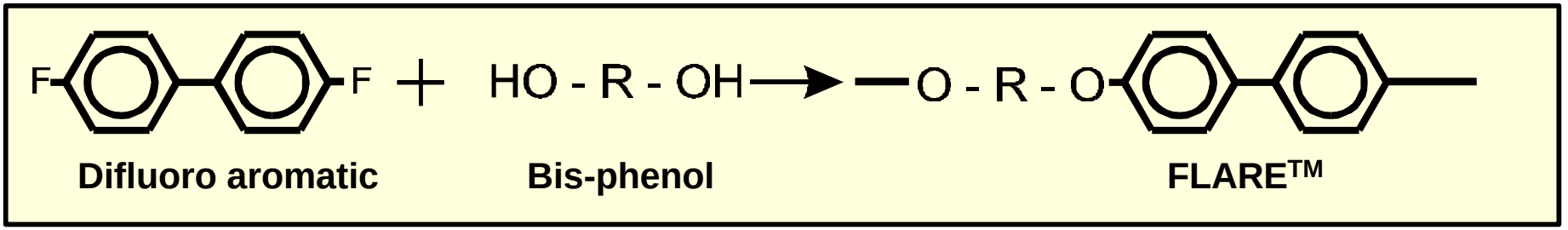
Major opportunity for polymers to replace inorganic dielectric materials.

Challenges:

- ***Thermal stability.***
- ***Compatibility and interface to silicon: tce and moisture.***
- ***Paradigm shift for industry.***

Polymeric Materials for Electronic Device Fabrication

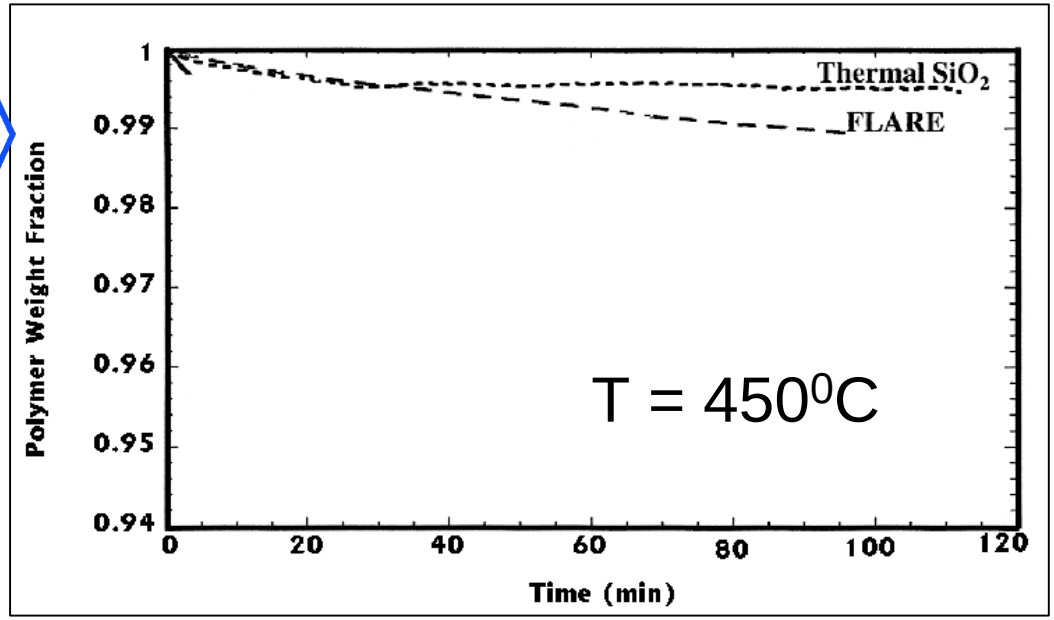
FLARE™, An Organic Polymer Dielectric for Integrated Circuit Interlayer Dielectric Applications.



Ar = R_1 FLARE 1.0X T_g = 270^{0}C

Ar = R_2 FLARE 2.0 T_g = >400^{0}C

- ***High thermal stability. <1%/hour, 450^{0}C.***
- ***Low moisture absorption: 0.4%.***
- ***Low dielectric constant: 2.43.***

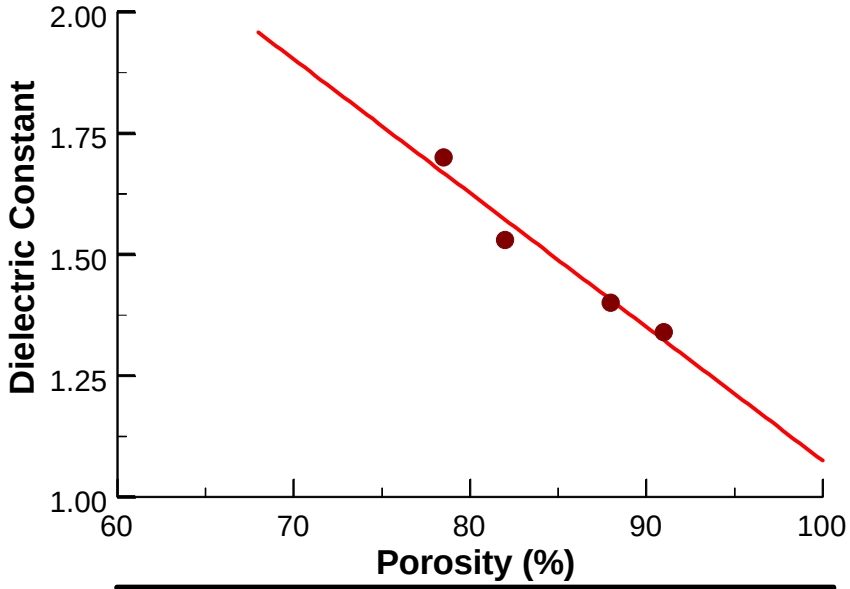


Opportunities for Integrated Circuit Manufacture - 2000

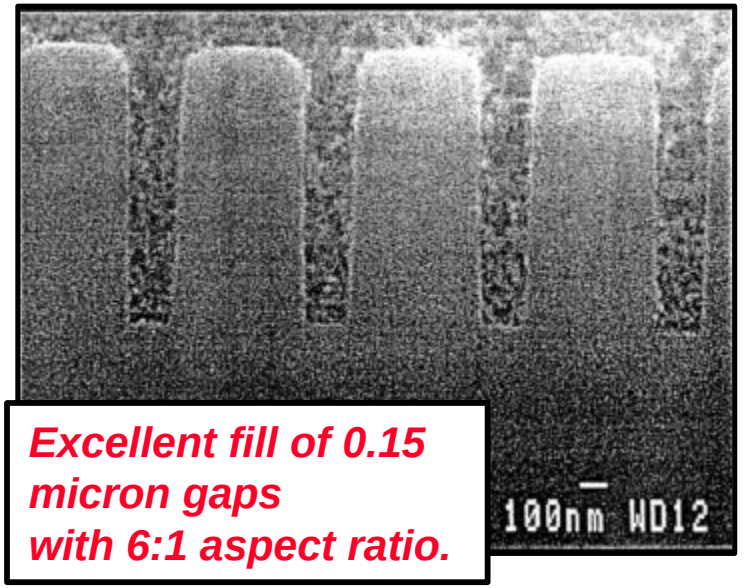
Nanoglass: Nanoporous silica for interlayer dielectrics.

Unique Properties

- **SiO_2 with tunable porosity.**
- **Tunable dielectric constant: 1.3 - 2.5.**
- **Thermally stable to over 500^{0}C.**
- **Narrow pore distribution ~ 20 nm.**
- **Excellent gap fill.**
- **Familiar chemistry and process.**



Commercialization through Nanoglas LLC,
a joint venture of AlliedSignal and NanoPore



Excellent fill of 0.15 micron gaps with 6:1 aspect ratio.

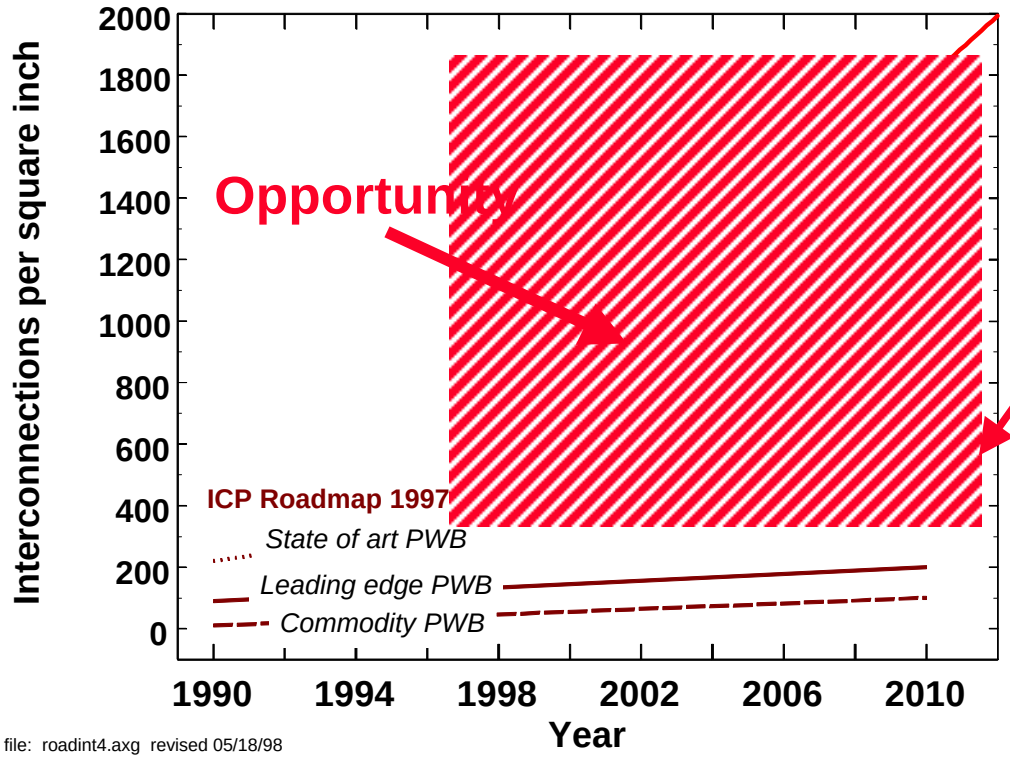
Critical needs for electronic packaging identified in SIA National Technology Roadmap for Semiconductors, 1997

- *Improved organic substrates for high I/O area array flip chip*
  - *Tg compatible with eutectic solder processing.*
  - *DK approaching 2.0.*
  - *Increased wireability at lower cost.*
  - *Lower TCE approaching 6.0 ppm/^{0}C.*
  - *Lower moisture absorption.*
- *Improved Underfills for high I/O area array flip chip.*
- *Reliability limits of flip chip on organic substrates.*
- *Integrated design tools and simulators to address chip, package, and substrate complexity.*

Opportunities for polymeric materials in electronic packaging abound!

Opportunities for polymeric materials in Electronic Packaging.

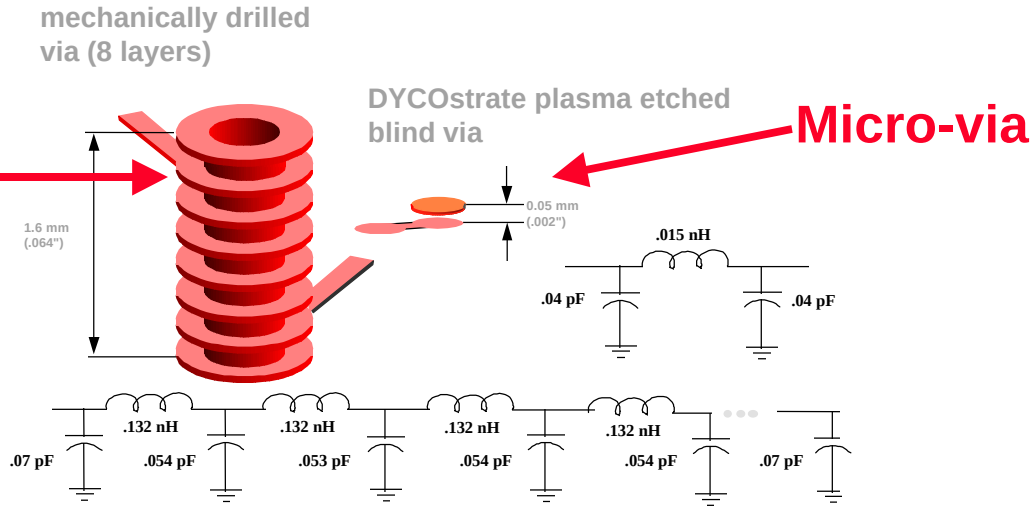
Electronic packaging roadmaps: Increased pin count and reduced package dimensions require paradigm shift in interconnection.



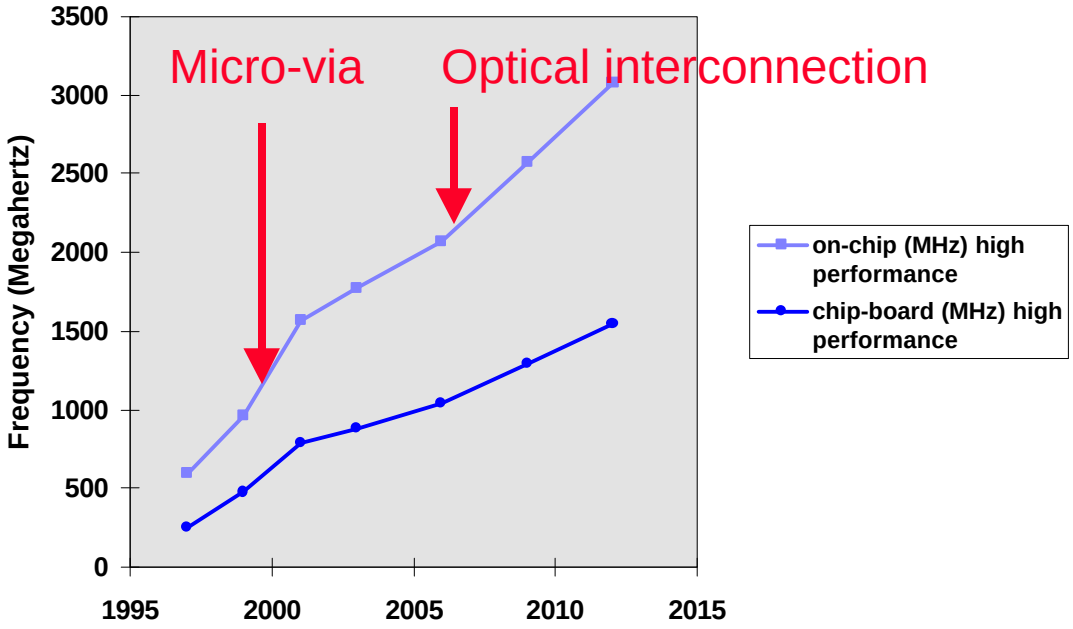
Semiconductor roadmap.

Printed Wiring board roadmap.

Opportunities for polymeric materials in Electronic Packaging.



Interconnect speed trends:



Opportunity: Advanced substrate materials to enable high density electronic packaging.

Challenges:

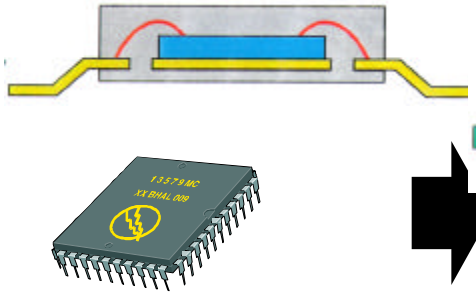
- Thermal stability.
- Moisture absorption.
- Thermal coefficient of expansion (Si=2 ppm/^{0}C….Cu=18 ppm/^{0}C).
- Dimensional stability.
- Lamination/build-up capability.
- Flame retardancy ……and many other things!

ASTI: AlliedSignal's new electronic packaging initiative

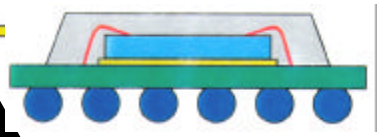
Electronic Packaging Evolution:

AlliedSignal Substrate Technology & Interconnect
Costa Mesa, California

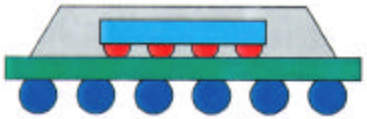
Quad Flat Pack

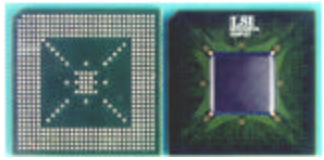


BGA-wire bond



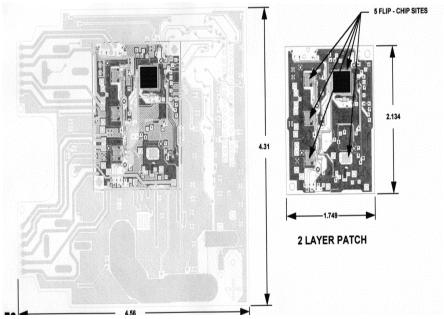
BGA-flip chip





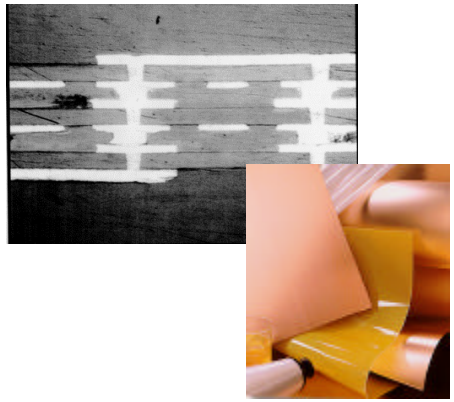
Chip scale pkg.

Chip on board



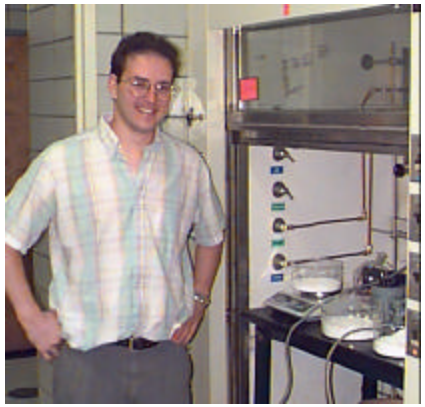
Unique technologies drive AlliedSignal packaging initiative

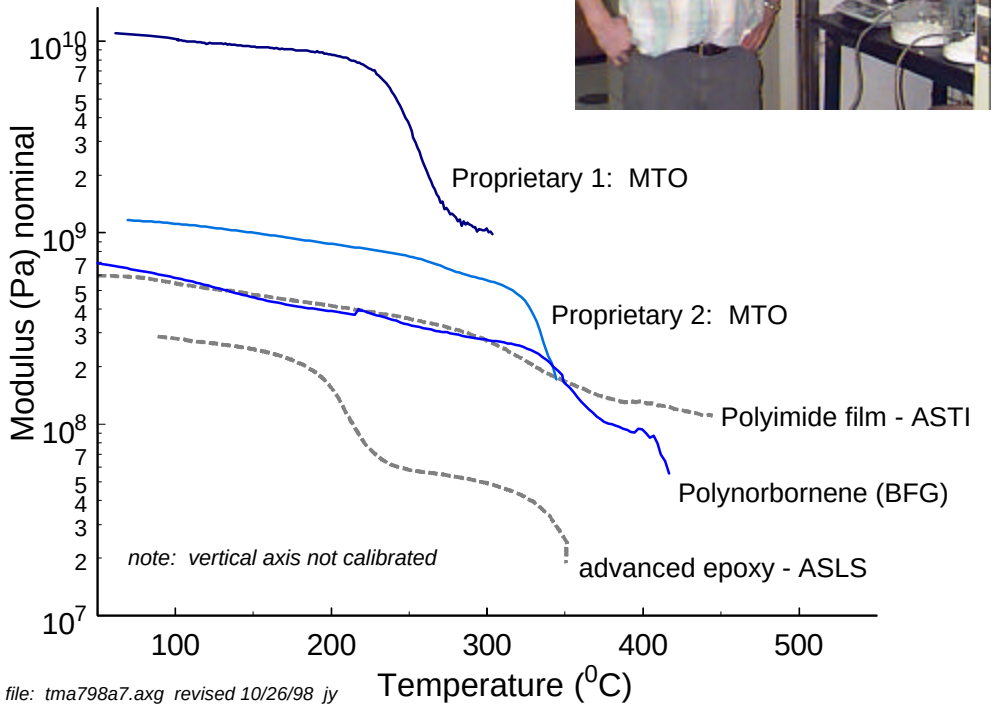
- ***High density circuitry from "layer pairs" give high yield.***
- ***Conductive inks provide key to multilayer construction.***
- ***Ultrastable™ substrate materials drive thermal stability, processing ease, insensitivity to moisture.***



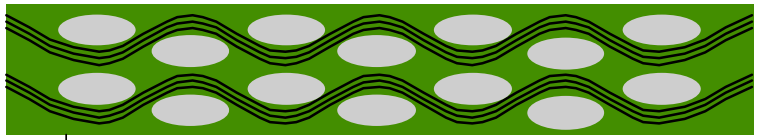
Advanced Substrates for Electronic Packaging

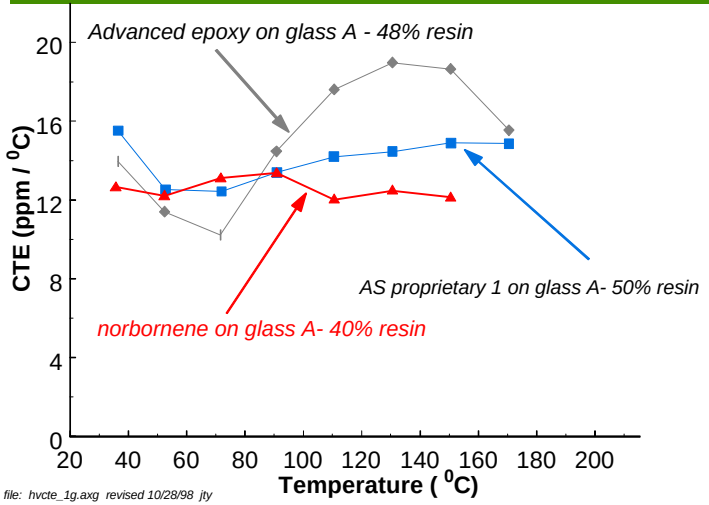
New polymeric materials provide properties needed for future generations of electronic packages.

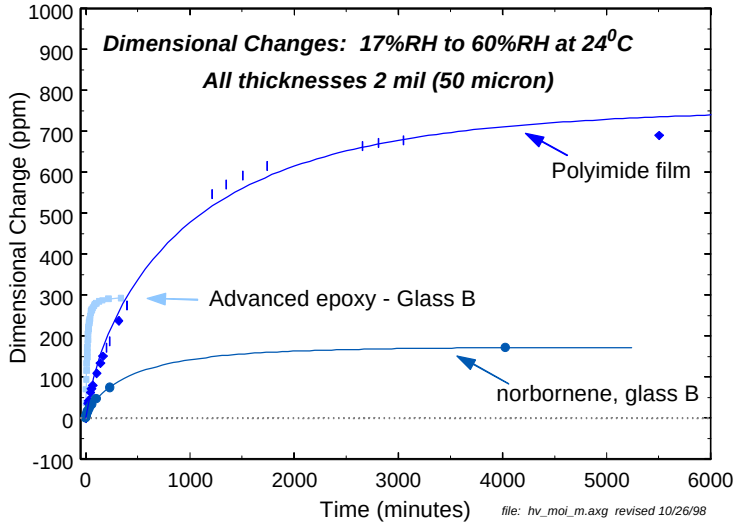




Typical substrate construction:

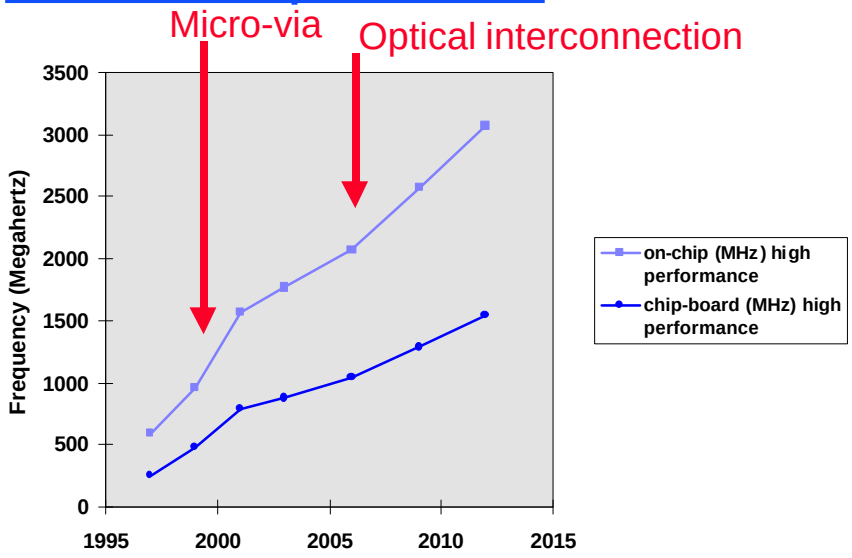




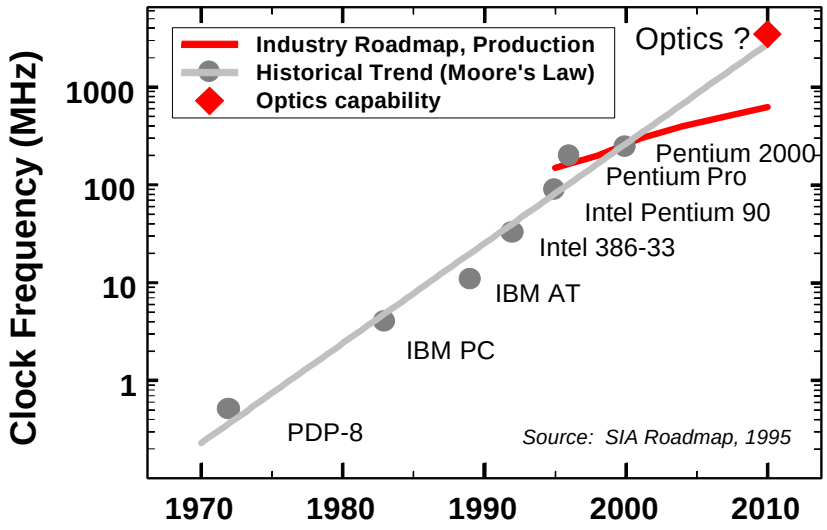


Higher speeds drive electronic industry toward optical interconnection.

Interconnect speed trends:



Semiconductor speed roadmap:



Opportunity: Polymeric optical interconnection for high speed communications.

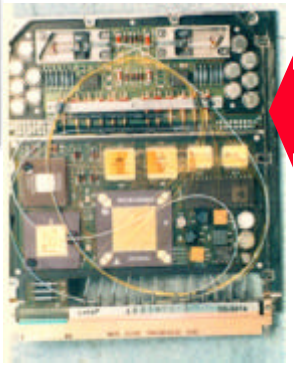
Challenges:

- **Low optical loss.**
  - **Absorption.**
  - **Scatter.**
- **Thermal stability.**
- **Precision control of dielectric constant (refractive index).**
- **…….and many others….**

AlliedSignal Polymeric Optical Interconnection Technology

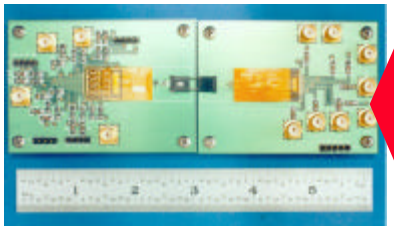
- Low loss materials
- Passive interconnection
- High thermal stability

1989



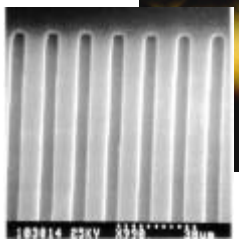
- Aerospace specification
- Deployment in sensor systems
- -55C to +125C

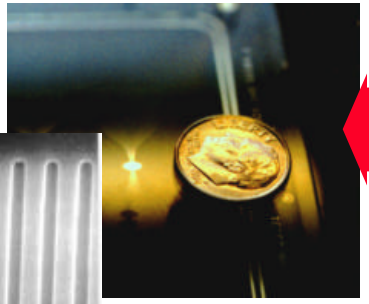
1992



- Parallel link
- Optical backplane

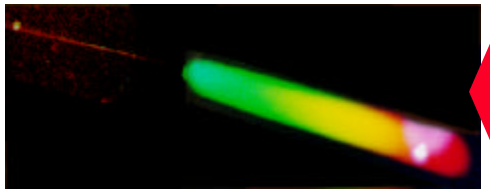
1995





- Single mode splitters
- Single mode passive interconnection
- Directional couplers

1996

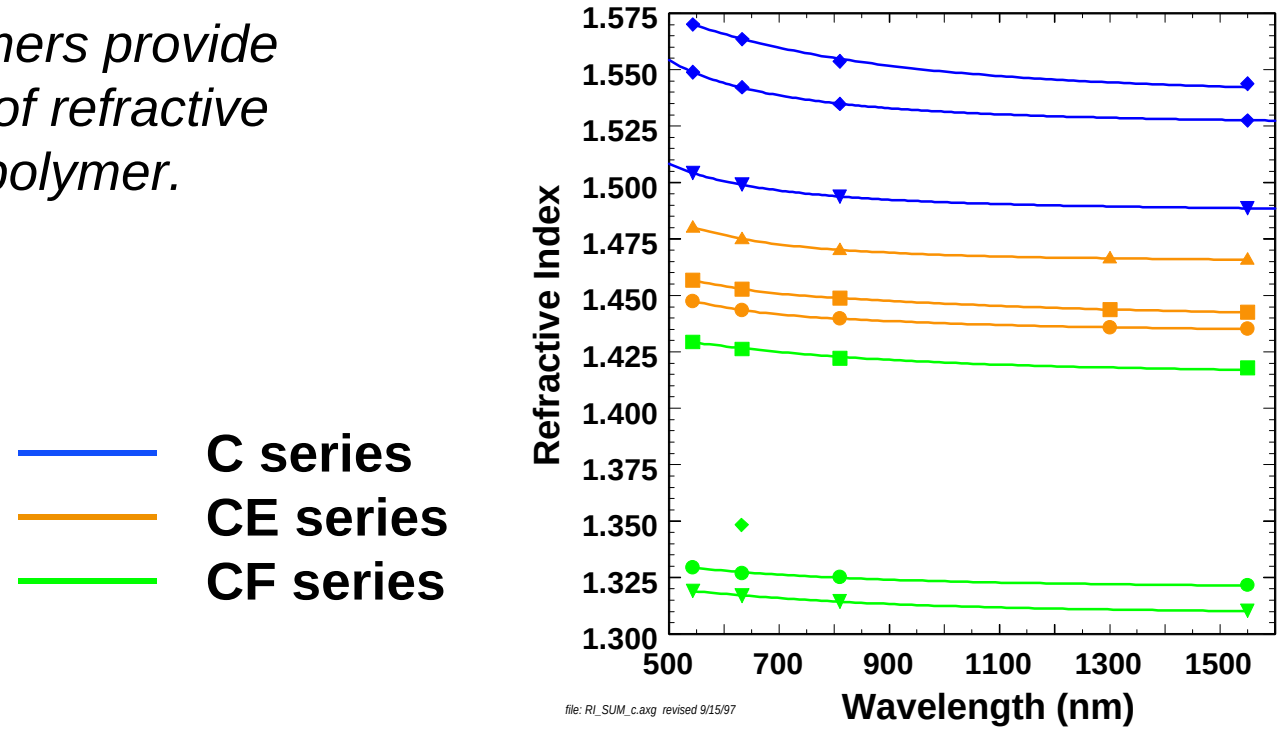


- Power splitter development
- Polymeric DWDM
- Parallel optial links

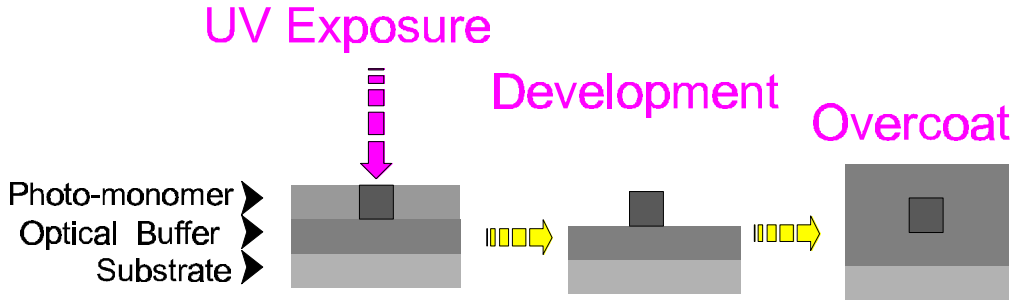
1998

Polymeric Materials and Fabrication for Low Loss Optical Interconnection

Miscible monomers provide precise control of refractive index of cured polymer.



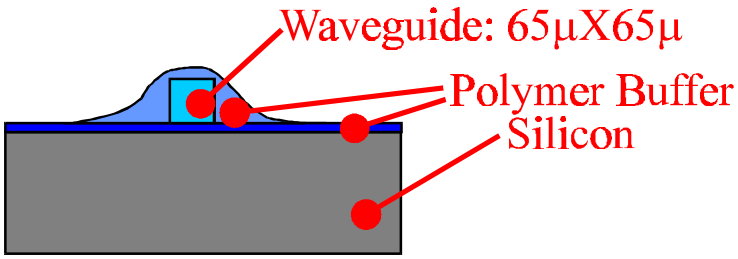
Lithographic processing provides precise control of waveguide geometry.

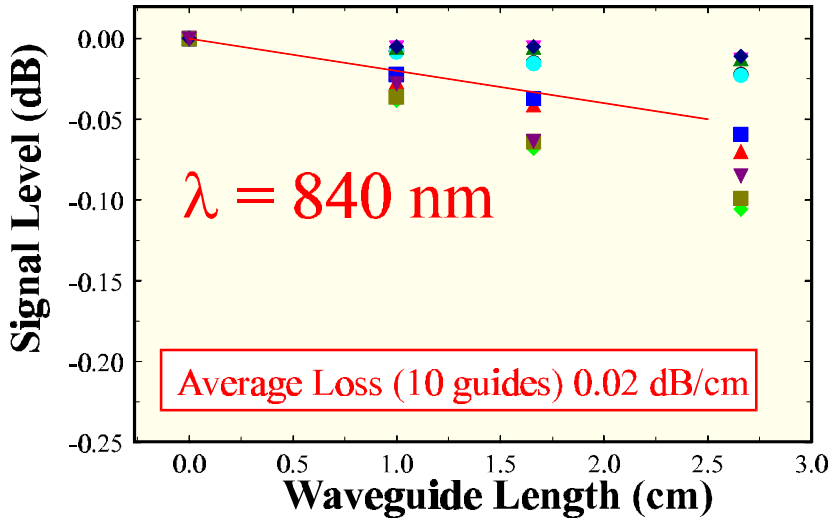


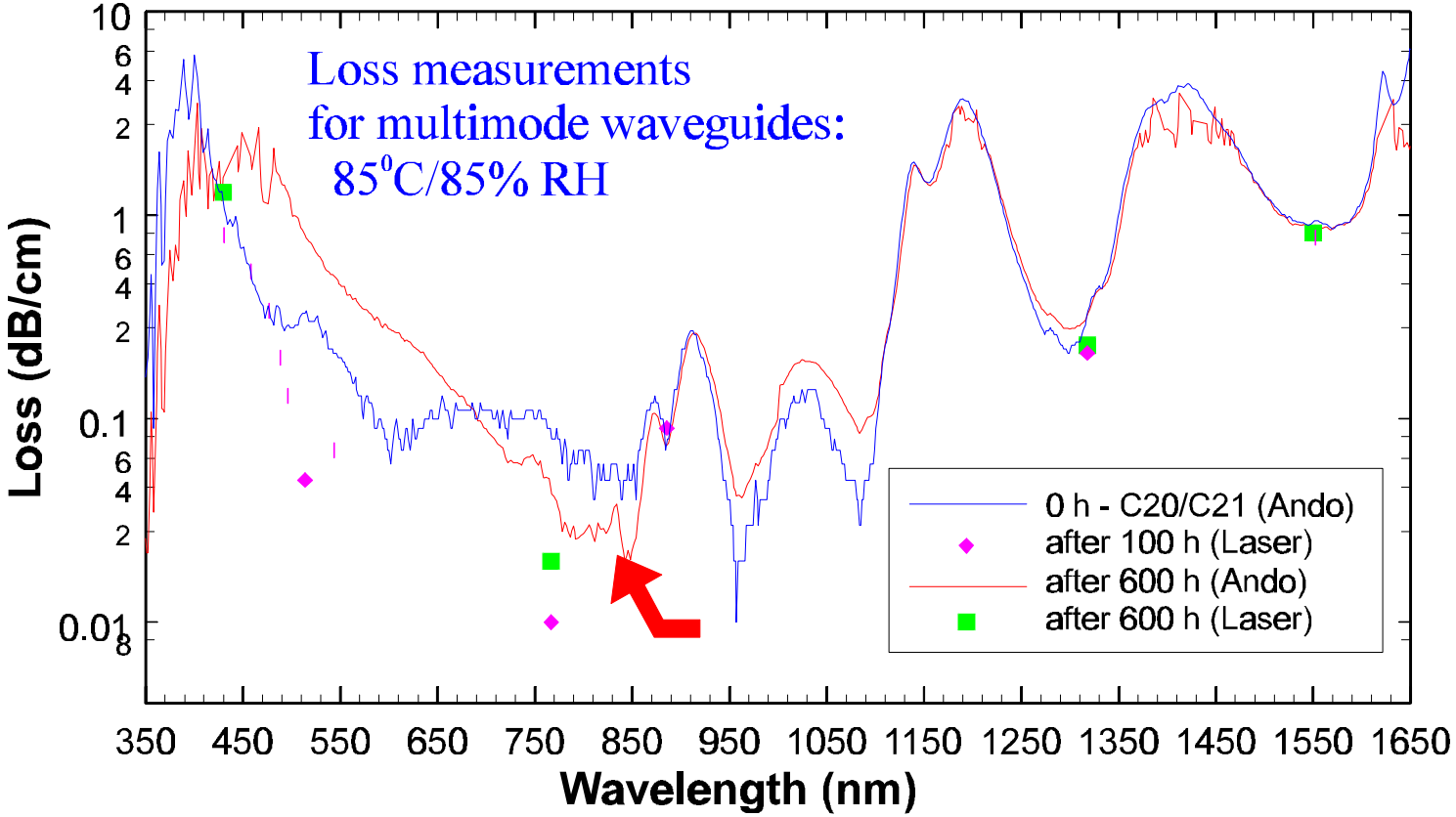
Optical device properties determined primarily by geometry of writing process or photomask and by refractive indexes of materials - both of which can be precisely controlled

Multimode Waveguide Losses:

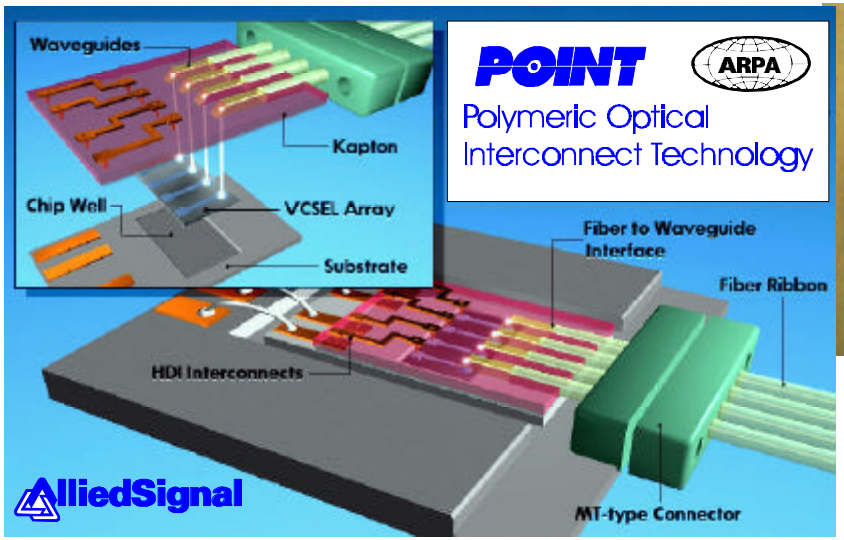
Cleave-back method

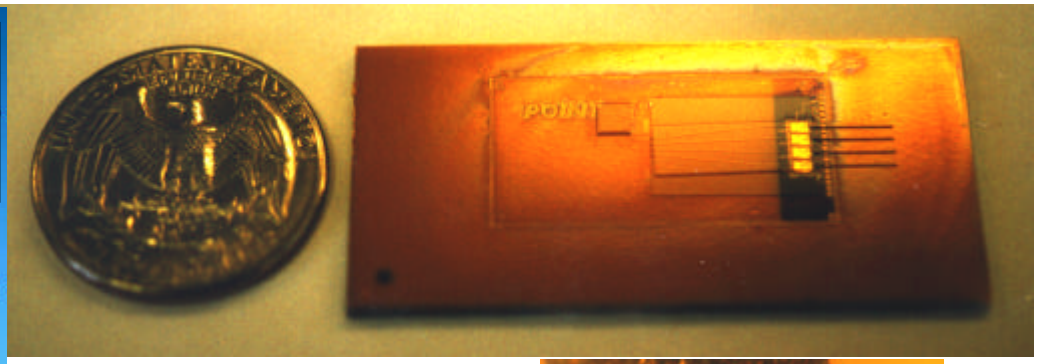


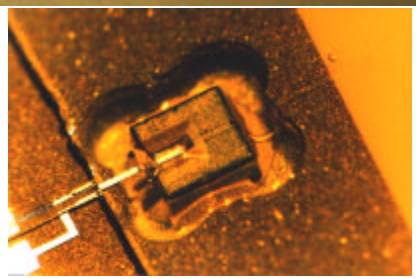




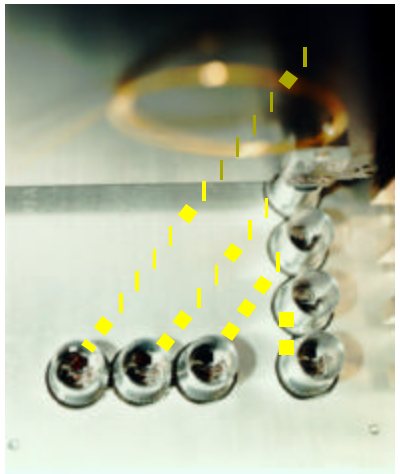
Polymer Optical Interconnect Technology: POINT (ARPA)

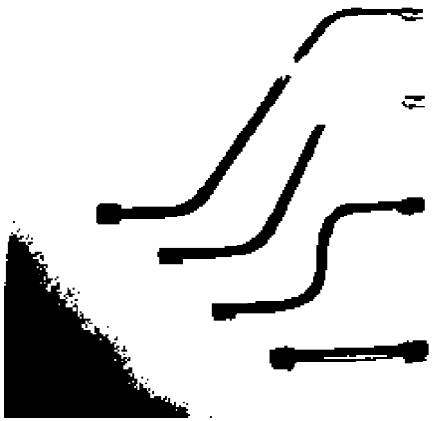


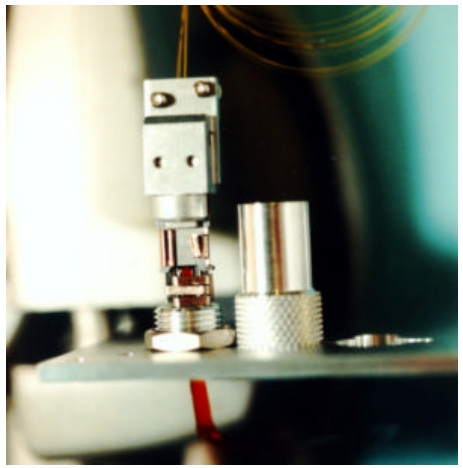




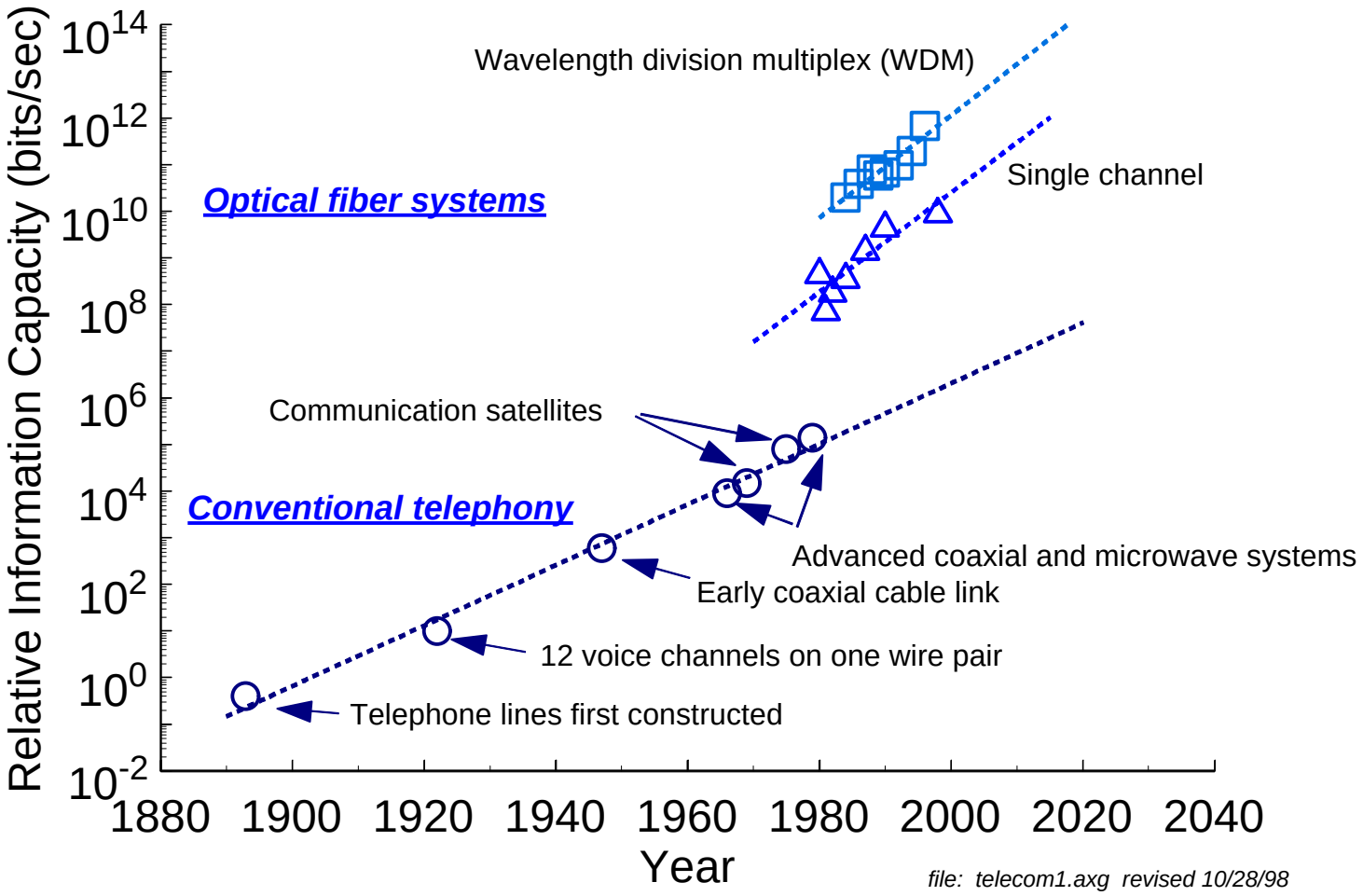
Optical Backplane System: FLASH (ARPA) and Obis (Navy)







Telecommunications roadmap transformed by optical interconnection and the internet.

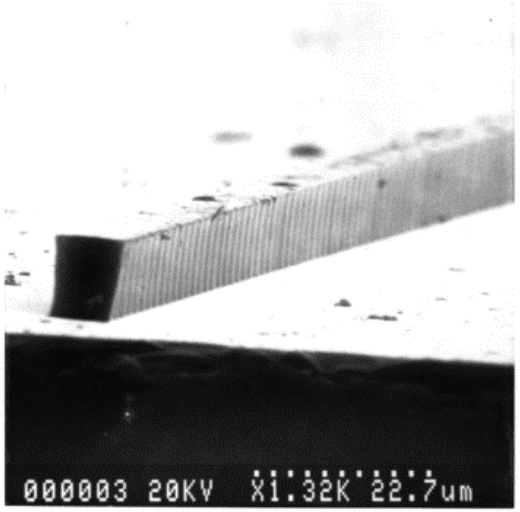


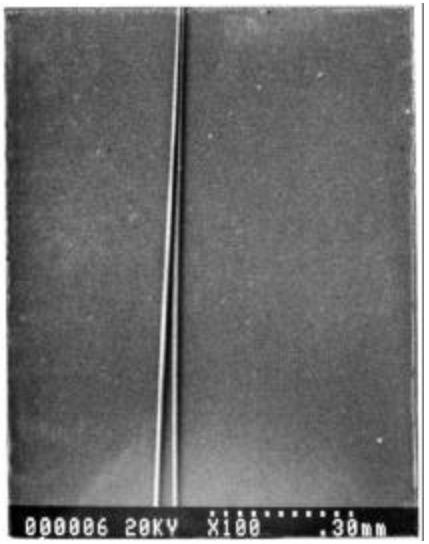
Hypothesis: Polymeric materials can provide inexpensive components which can enable “fiber to the home”.

Polymeric Single Mode Devices for Telecommunications

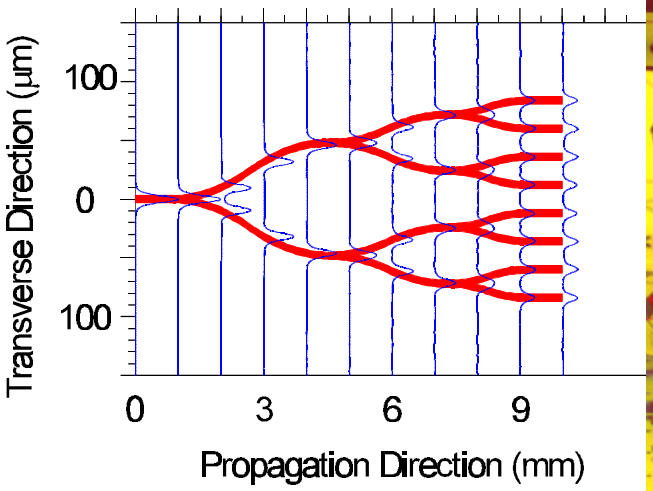
Single mode device fabrication using microlithography

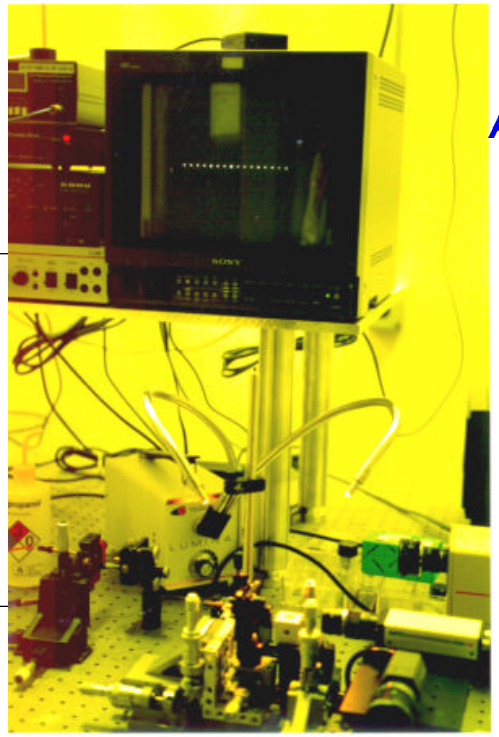
$\delta n = 0.0075$



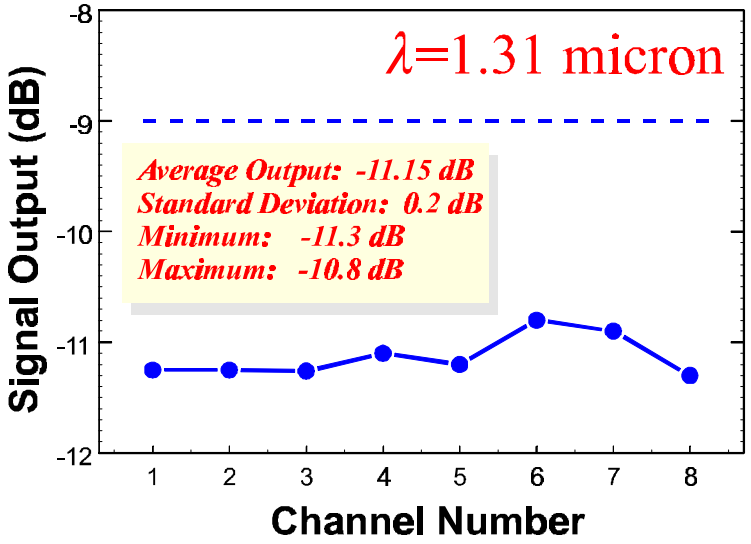


Optical device modeling and characterization

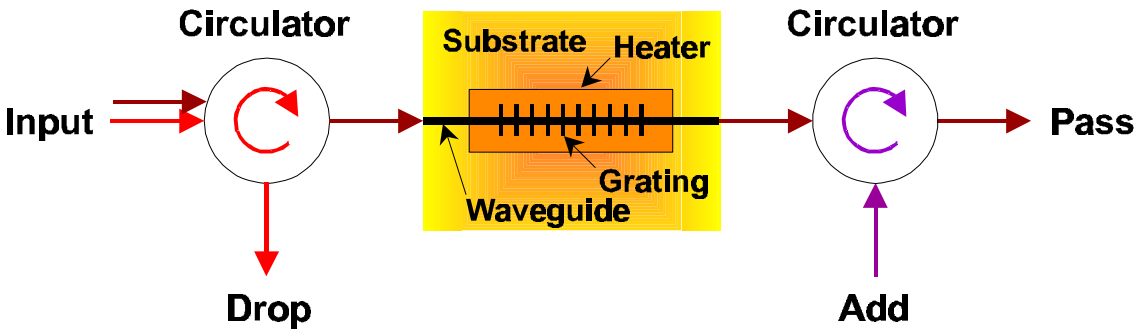


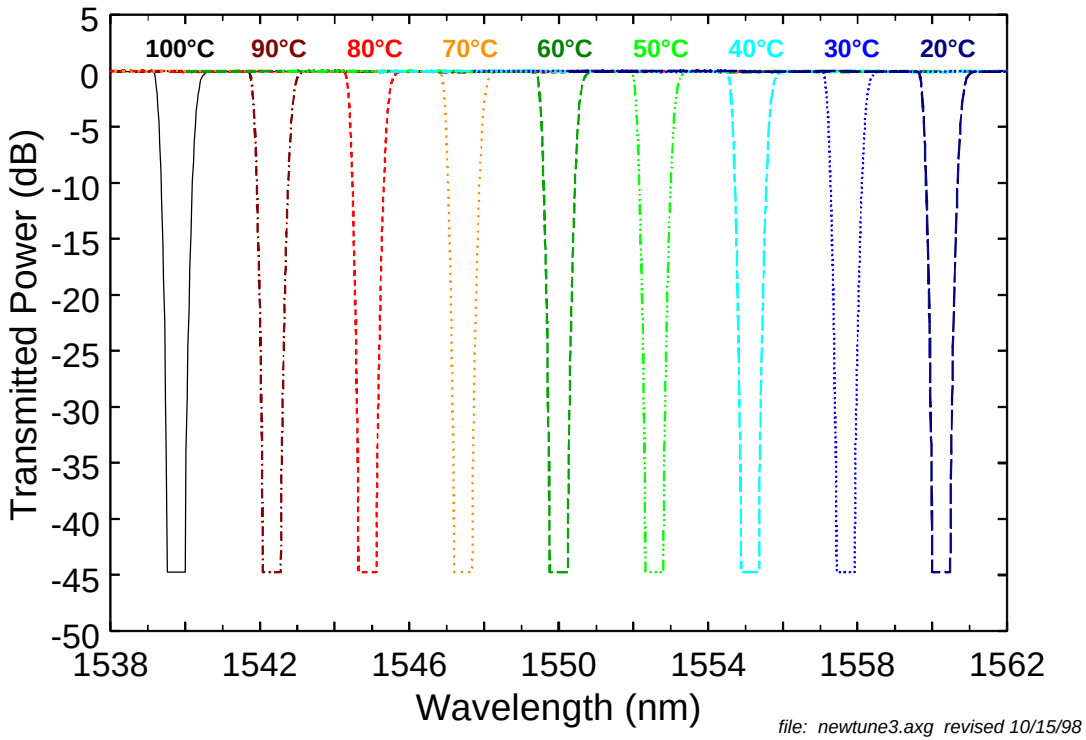


AlliedSignal Molded 1X8 Single Mode Coupler



Polymeric gratings enable low-cost “fiber to the home” and suggest many other opportunities…..





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Conclusions and commentary: NIST Programs

Opportunities for organic materials in electronic industry abound!

- Many needs exist for “passive” applications.
- Properly constructed consortia can drive significant new business development in the electronics industry (example ASTI of AlliedSignal).
- Some specific areas of opportunity include:
    - Optical interconnection.
    - Advanced electronic substrates.
    - Dielectric materials for semiconductor fabrication.
    - Electronic device packaging.

Realities must be recognized and addressed.

- Teaming of materials development with applications engineering within industry driver is critical.
- Business development activities must follow industry roadmaps….industry is evolutionary in nature.
- Timing is crucial: must be at the right place at the right time.
- Genuine business development commitment is critical for success of NIST programs (but note: business world changes rapidly).
- Credibility of organic materials is a barrier, especially where inorganic or semiconductor materials are current paradigm.
- Materials development must be sensitive to *all* of the application requirements - should go hand in hand with applications development.
- Economic issues need to be understood and negotiated up front and must take into account evolution of marketplace.